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(54) **Electrohydraulic system.**

(57) In a fork lift vehicle (10) that includes an extensible boom (14) pivoted at one end to a base (12) and carrying a fork platform (18) at the opposing end, fork height above a horizontal plane that intersect the boom/base pivot axis is determined upon initiation of an automatic mode of operation. A pair of sensors (44) provide associated signals as functions of boom extension and boom angle respectively. Boom extension is directly controlled by the vehicle operator during the automatic mode of operation, while boom angle is controlled as a combined function of the angle and extension sensor output signals (R3,A3), and desired platform height above horizontal. Thus, velocity of motion at the boom end platform remains directly controlled by the vehicle operator while verticle height of the platform forks is maintained.

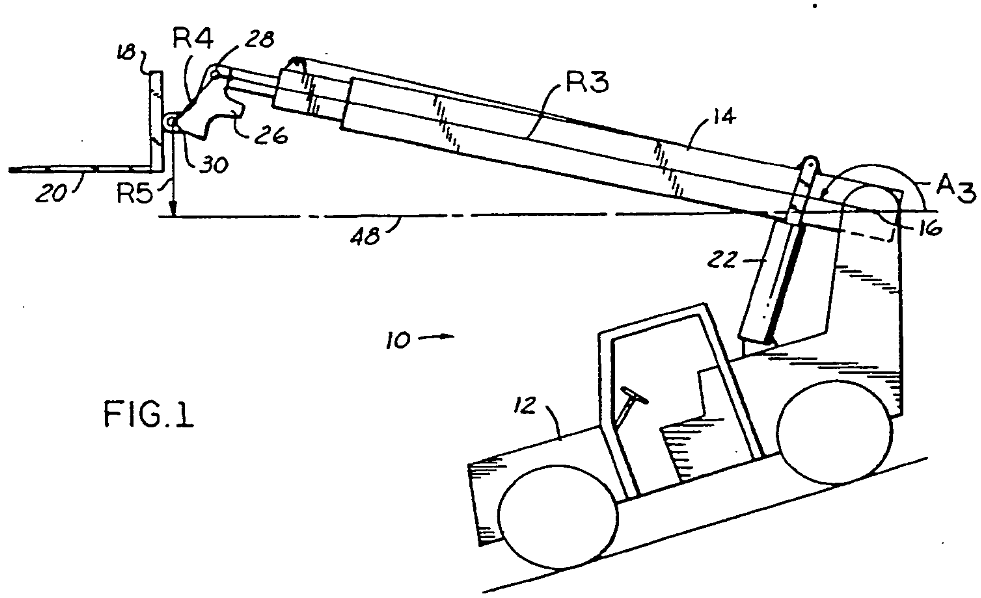

FIG.1

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Electrohydraulic System

The present invention is directed to electrohydraulic systems for controlling motion at a load, and more particularly to systems for controlling motion at the free end of an extensible boom.

Background and Objects of the Invention

A typical rough-terrain fork lift includes a wheeled base, an extensible boom pivotally mounted at one end to the base and a fork platform carried at the base-remote or free end of the boom. Hydraulic actuators are coupled to associated hydraulic valves for controlling pivotal motion and extension of the boom with respect to the base as functions of operator input command signals. There are numerous instances in which operators desire to extend or retract the platform forks in a horizontal plane, either above or below the horizontal plane of the boom pivot axis. It is difficulty however, to control both extension and angle of the boom concurrently. This problem is compounded when the platform forks are at a substantial height, or where the operator's vision is entirely or partially blocked by walls, construction or equipment.

Similar problems arise in other applications involving control of a load carried at the free end of a boom arm. For example, crane operators loading a ship often desire to maintain a constant height of a crane load while changing boom position. The operator may want to return repeatedly to a particular radius from the boom pivot to drop or pick up a load into or from a ship's hold for transfer from or to a dock. In another application, the operator of an earth excavator may want the bucket at the free end of the excavator boom to return to a certain depth after numerous machine cycles for producing a level trench.

It is a general object of the present invention to provide an electrohydraulic control system for automatically maintaining a predetermined orientation of a load while moving the load through at least two degrees of motion. More specifically, it is an object of the present invention to provide an electrohydraulic boom control system for maintaining a predetermined or preset orientation at the boom free end while changing angle and extension of the boom with respect to the support base. yet more particularly, as applied specifically to fork lift vehicles, it is an object of the present invention to provide a control system for maintaining constant height of the fork platform while selectively extending or retracting the boom at a rate directly controlled by the operator.

Summary of the Invention

In an electrohydraulic system that includes a load and electrohydraulic mechanisms for moving the load through at least two degrees of motion, electronic circuitry for automatically maintaining a predetermined orientation at the load includes a pair of sensors for providing respective signals as functions of associated degrees of motion at the load, circuitry responsive to an operator for directly controlling one degree of motion at the load, and feedback circuitry responsive to the sensor signals for controlling the other degree of motion as a function of operator-control motion in the one degree. As applied specifically to controlling motion at the free end of an extensible boom, the control circuitry is responsive to operator input command signals in a manual mode of operation for directly controlling both boom extension and boom angle with respect to the support base, and in an automatic mode of operation for controlling one of such motions as a function of the other independently of direct operator input and to maintain a desired orientation at the boom end selected upon entry of the automatic mode of operation.

In a preferred implementation of the invention for maintaining horizontal orientation of platform forks in a fork lift vehicle, fork height above a horizontal plane that intersects the boom/base pivot axis is determined upon initiation of the automatic mode of operation. A pair of sensors provide associated signals as functions of boom extension and boom angle respectively. Boom extension remains directly controlled by the operator during the automatic mode of operation, while boom angle is controlled as a combined function of the angle and extension sensor output signals, and desired platform height above horizontal. Thus, velocity of motion at the boom platform end remains directly controlled by the vehicle operator.

Brief Description of the Drawings

The invention, together with additional objects, features and advantages thereof, will be best understood

from the following description, the appended claims and the accompanying drawings in which:

FIG. 1 is a schematic diagram of a rough-terrain fork lift vehicle in which the invention is implemented in accordance with a presently preferred embodiment thereof; and

FIG. 2 is a function block diagram of the electrohydraulic control system in the vehicle of FIG. 1.

Detailed Description of Preferred Embodiment

FIG. 1 illustrates a rough-terrian fork-lift vehicle 10 that includes a wheeled base 12. An extensible boom 14, typically comprising multiple telescoping sections, is coupled at one end to base 12 to pivot about an axis 16 at fixed position with respect to base 12. A platform 18 is carried at the base-remote or free end of boom 14, and has a pair of fork blades 20 projecting outwardly therefrom. A hydraulic actuator or cylinder 22 (FIGS. 1 and 2) is coupled between base 12 and boom 14 for controlling pivotal motion of boom 14 about axis 16. A second actuator or cylinder 24 (FIG. 2) controls extension of boom 14 with respect to axis 16. An extension 26 is pivotally coupled by pins 28, 30 to the free end of boom 14 and platform 18 respectively. Pivotal motion of platform 20 about pin 30 is slaved (by means not shown) to motion at cylinder 22. To the extent thus far described, vehicle 10 is of conventional construction.

FIG. 2 illustrates boom control system 32 as comprising a joystick or the like 34 for generating electrical EXTEND and LIFT motion command signals Ce, Cl as a function of manipulation by a vehicle operator. A first valve drive amplifier 36 receives the EXTEND command signal Ce from joystick 34, and provides a corresponding output to an electrohydraulic valve 38 that feeds hydraulic fluid from a source (not shown) to cylinder 24 as a function of such output signal. Likewise, a second valve drive amplifier 40 receives the LIFT command signal Ce from joystick 34, and provides a corresponding output signal to an electrohydraulic valve 42 that feeds fluid to cylinder 22 as a function of such output signal. Thus, to the extent thus far described, boom angle and extension are directly controlled by the vehicle operator through manipulation of joystick 34.

In accordance with the present invention, a first sensor 44 is coupled to boom 14 for providing a sensor output signal R3 (FIGS. 1 and 2) as a function of extension or length of boom 14 from pivot axis 16. A second sensor 46 is coupled to boom 14 for providing a second sensor signal A3 (FIGS. 1 and 2) as a function of angle of boom 14 about axis 16 with respect to a horizontal plane 48 (FIG. 1) at intersects axis 16. Sensor 44 maybe of any suitable type mounted within or adjacent to boom 14 to provide an output as a function of extension thereof. Likewise, sensor 46 maybe of any suitable type, with a pendulum-type sensor mounted on boom 14 adjacent to pivot 16 being presently preferred so as to be independent of orientation of vehicle base 12.

A control circuit 50 (FIG. 2), which is preferably microprocessor-based, includes a first functional block or module 52 that receives sensor signals R3, A3 and calculates height R5 of platform pin 30 (FIG. 1) above horizontal plane 48. The signal R5 at the output of calculation block 52 is fed through a normally open switch 54 to a second block or module 58. Block 58 receives boom extension sensor signal R3 as a second input, and provides a desired boom angle command signal Ac to a comparator 60. Comparator 60 receives a second input A3 from sensor 46, and provides an output signal E to a valve drive amplifier 62 indicative of a difference or error between the desired and actual boom angle signals Ac and A3. A second switch 64 normally connects the input of valve 42 to amplifier 40, and may be selectively switched to connect the valve input to the output of amplifier 62.

Suitable valve drive amplifiers 36, 40 and 62, suitable valves 38, 42, and suitable actuator cylinders 22, 24 are disclosed, for example, in U.S. Patent No.- 4,757,747, which also discloses a microprocessor-based controller in which circuit 50 may be implemented.

In operation, height R5 is continually calculated at block 52 as a function of the equation:

$$R5 = R4 * \cos(A3) + R3 * \sin(A3) \qquad (1)$$

where R3 is length of boom 14 as shown in FIG. 1, R4 is separation between pivots 28, 30, and R5 is height of pin 30 above horizontal plane 48. Desired lift angle command Ac is calculated at block 58 in accordance with the equation:

$$Ac = 2 * \tan^{-1} \left[\frac{R3 \pm (R3^2 + R4^2 - R5^2)^{\frac{1}{2}}}{R4 + R5} \right] \qquad (2)$$

During manual operation with switches 54, 64 in the position shown in FIG. 2, boom angle cylinder 22 is driven as a direct function of the joystick operator LIFT command signal through amplifier 40, switch 64 and valve 42. Height R5 is continually calculated and indicated at 52, but ignored. When the operator desires to enter an automatic mode of operation, switches 54, 64 are switched, the most current height signal R5 is fed to module 58, and thereafter valve 42 and cylinder 22 are driven by amplifier 26 and lift calculation block 58 as a function of height signal R5, boom extension sensor signal R3 and boom angle signal A3 as previously described. Thus, boom extension is directly controlled by the operator, while boom angle is automatically indirectly controlled so as to maintain height R5 constant as the boom is extended and retracted. The speed of such extension is directly controlled by the operator.

Claims

1. An electrohydraulic boom control system comprising a base (12), an extensible boom (14) coupled to said base (12) for pivotal motion about an axis (16) and means (18) at an end of said boom remote from said axis (16) for performing controlled operations, first electrohydraulic means (22, 42) coupling said boom (14) to said base (12) and responsive to first electrical command signals for pivoting said boom with respect to said base about said axis (16), second electrohydraulic means (24, 38) coupled to said boom (14) and responsive to second electrical command signals for controlling length of said boom with respect to said axis, characterized by
means for moving said boom-end means (18) while maintaining said boom-end means at predetermined orientation comprising:
means (34) responsive to an operator for providing one of said first and second command signals (Ce, Cl), first sensor means (44) coupled to said boom (14) for providing a first sensor signal (R3) as a function of boom extension, second sensor means (46) coupled to said boom (14) for providing a second sensor signal (A3) as a function of boom angle about said axis, and means (50, 64) responsive to said first and second signals (R3, A3) in a first mode of operation for providing the other of said first and second command signals.

2. The system set forth in claim 1
wherein said other-signal-providing means (50, 64) comprises means responsive to an operator in a second mode of operation for providing said other of said command signals, and means (54, 64) for selecting between said first and second modes of operation.

3. The system set forth in claim 2
wherein said other-signal-providing means (50) comprises means (54, 64) responsive to said selecting means for determining a predetermined parameter (R5) of said boom-end means (18) with respect to horizontal (48) upon selection of said first mode of operation, and means for generating said second command signal (l) as a function of said first and second sensor signal (R3, A3) so as to maintain said first parameter (R5) constant.

4. The system set forth in any of claims 1 to 3
wherein said means (34) responsive to an operator for generating one (Ce) of said command signals (Ce, Cl) includes means (24, 36, 38) for controlling one of said extension and angle motions of said boom (14) as a direct function of said one (Ce) of said command signals, sensor means (44, 46) responsive to position of said boom end (18), means (50) responsive to said sensor means (44, 46) for generating the other (l) of said command signals, and means (42, 44) responsive to said other command signal (l) for controlling the other of said extension and angle motions.

5. The system set forth in any of claims 1 to 4
including means (60) for automatically maintaining a predetermined condition at said load comprising:
first and second sensors (44, 46) for providing respective signals as functions of motion of said load in said two degrees of motion, means (34) responsive to an operator for directly controlling one degree of motion at said load, and means responsive to said sensor signals (R3, A3) for controlling the other said degree of motion as a function of motion in said one degree.

6. The system set forth in any of claim 1 to 5
including an axis (16), means (52) responsive to said first and second sensor signals (R3, A3) for determining height of said platform (18) with respect to a horizontal plane (48) intersecting said axis (16), and command means (34, 50) responsive to an operator and to said sensor singals (R3, A3) for providing said first and second command signals so as to maintain said height (R6) constant.

7. The system set forth in claim 6
wherein said command means comprises means responsive to an operator for generating input command

signals, means for providing one of said first and second command signals as a direct function of said input command signals, and means responsive to said sensor signals for providing the other of said first and second command signals, such that velocity of motion at said platform is controlled directly by said operator input command signals.

8. The system set forth in claim 7 wherein said command means comprises means for generating said second command signal as a direct function of said input command signals, and means responsive to a difference between said second sensor signal and said height for generating said first command signal.

9. The system set forth in claim 8 wherein said command means comprises means responsive to said difference for generating a desired first command signal, and means responsive to a second difference between said desired first command signal and saif rist sensor signal for generating said first command signal.

10. The system set forth in claim 8 wherein said command means further comprises means for selecting between manual and automatic modes of operation, and means for generating said first command signal as a function of said input command signals in a manual mode of operation.

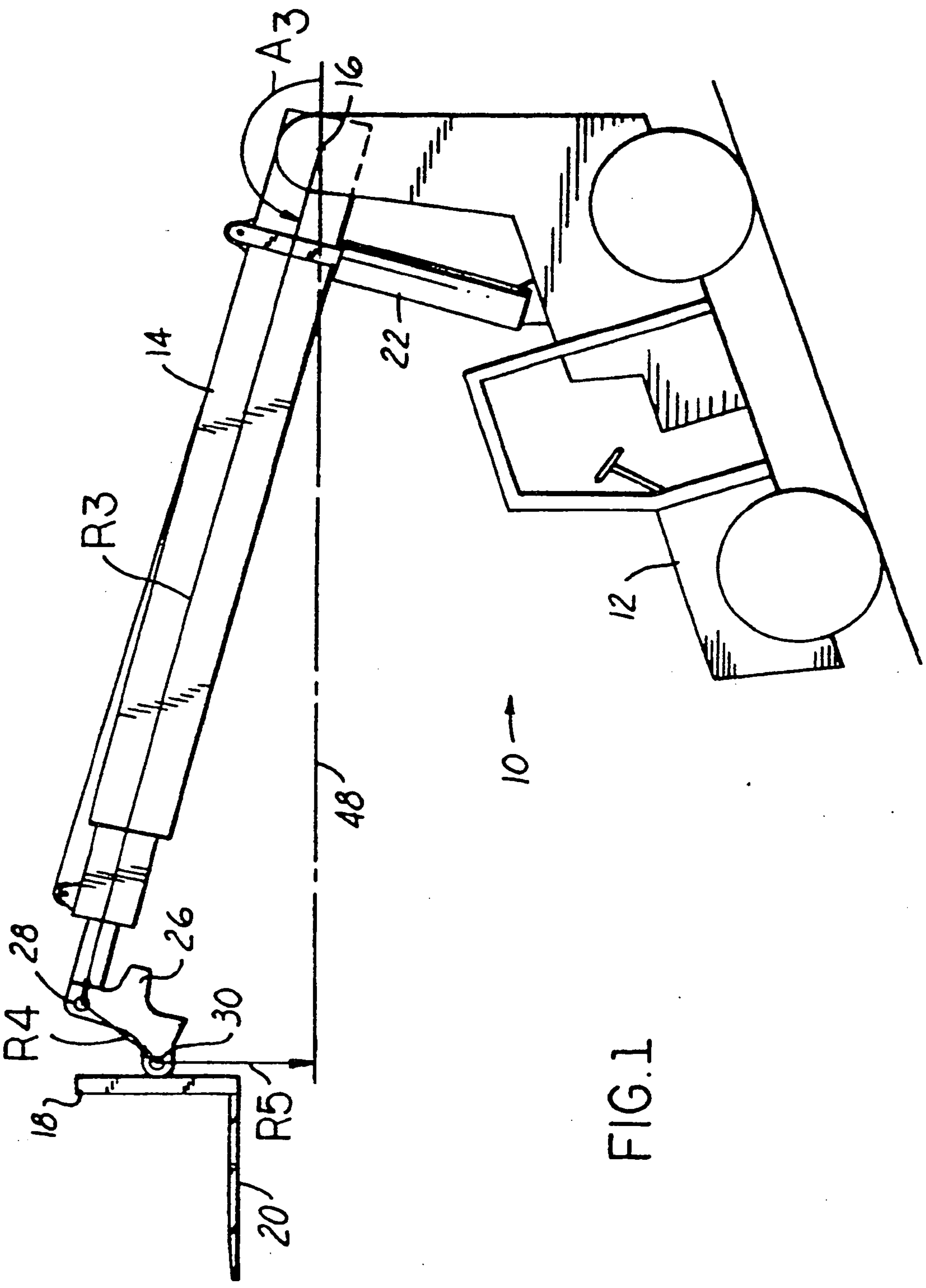

FIG.1

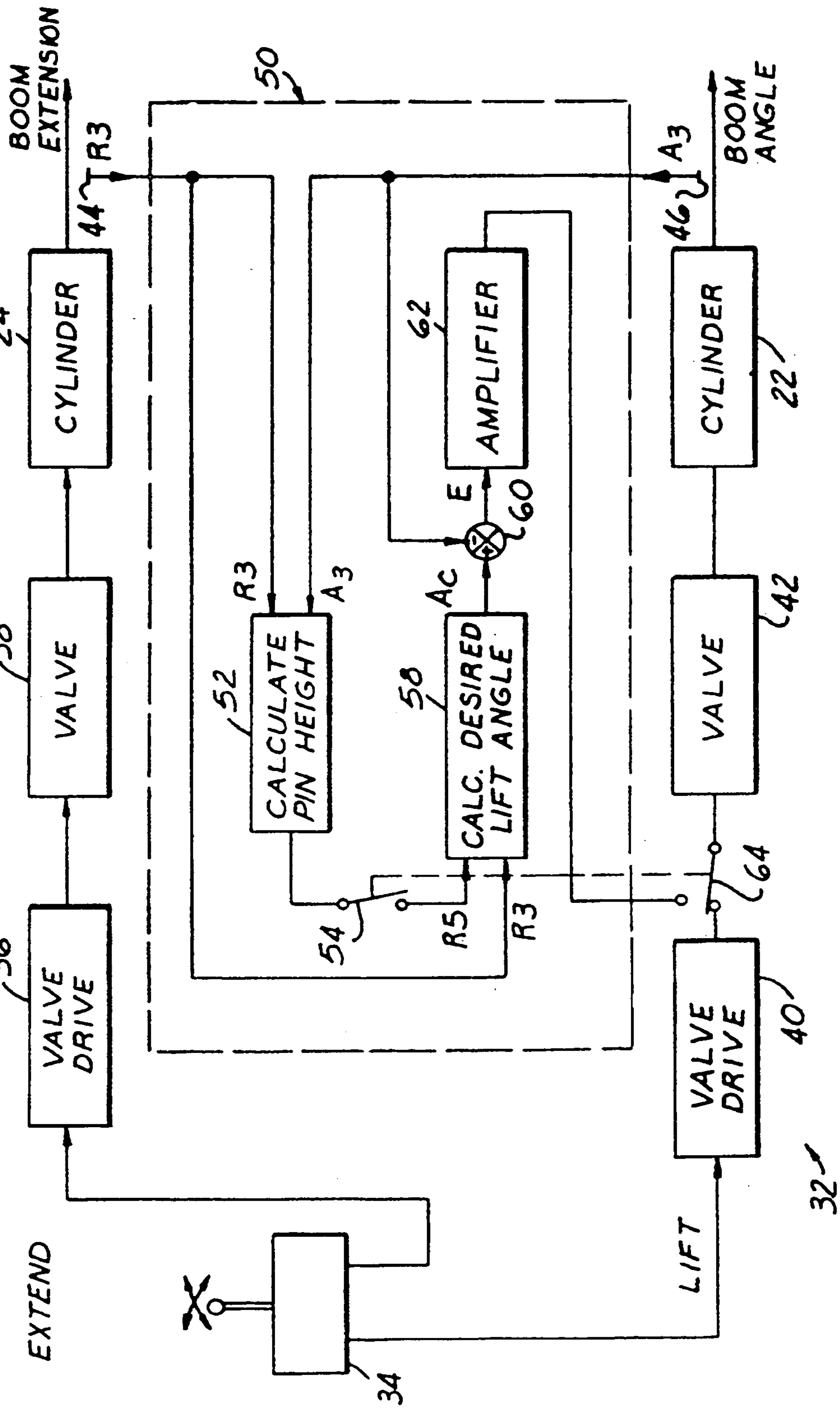
BOOM EXTENSION
R3
44
24
CYLINDER
38
VALVE
36
VALVE DRIVE
EXTEND
34
50
52
CALCULATE PIN HEIGHT
R3
A3
58
CALC. DESIRED LIFT ANGLE
Ac
60
E
62
AMPLIFIER
54
R5
R3
64
A3
46
BOOM ANGLE
CYLINDER
22
VALVE
42
VALVE DRIVE
40
LIFT
32

FIG.2

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EUROPEAN SEARCH REPORT

Application Number

EP 90 10 8550

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	US-A-4 553 899 (MAGNI) * Figures; column 1, lines 20-25; column 2, lines 53-68; column 5, lines 25-32; column 3, lines 30-48; column 3, line 66 - column 4, line 62 * ---	1	B 66 F 9/065
A	FR-A-2 183 782 (CLARK EQUIPMENT CO.) * Page 2, lines 2-9; pages 5,6; page 10, lines 8-25; claim 1; figures 2,5 * ---	1	
A	WO-A-8 801 600 (ÖSA AB) * Abstract; page 2, lines 9-27; page 3, lines 1-22; page 7, line 35 - page 8, line 22; figures * ---	1	
A	EP-A-0 288 314 (LASER ALIGNMENT INC.) * Abstract; page 17, line 61 - page 18, line 33; figures 1,2,11-16 * ---	1	
A	GB-A- 966 609 (MOLINS MACHINE CO., LTD) * Page 4, line 115 - page 5, line 8; figure 5 * ---	1	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	FÖRDERN UND HEBEN, vol. 34, no. 12, December 1984, pages 929-932, Mainz, DE; H.H. COHRS: "Verwendungsmöglichkeiten der Mikroelektronik in Tagebaugeräten" * Pages 929-932 * ---	1	B 66 F E 02 F
P,A	DE-A-3 800 930 (HERBST FÖRDER- UND HEBETECHNIK) * Claims 1-3; figure 9 * ---	1	
A	DE-A-3 602 213 (CORDES) --- -/-		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	09-08-1990	GUTHMULLER J.A.H.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
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& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

Application Number

EP 90 10 8550

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	DE-A-3 310 568 (LIEBHERR-HYDRAULIKBAGGER GmbH) -----		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	09-08-1990	GUTHMULLER J.A.H.

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